RAPID USER ACQUISITION BY A GROUND-BASED BEAMFORMER

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BACKGROUND OF THE INVENTION

The present invention relates generally to ground-based beamformers. More specifically, but without limitation thereto, the present invention relates to finding a cell in which a specific user is located within the coverage area of a stratospheric transponder platform linked to a ground-based beamformer.

An antenna array on a stratospheric transponder platform can support multiple subscribers dispersed over a wide coverage area. To reduce weight, power consumption, and cost of the stratospheric transponder platform, a ground-based digital beamformer may be used that performs the beam calculations on the ground from a ground station linked to the antenna elements on the stratospheric transponder platform. In this arrangement, the element excitation signals are passed between the antenna elements on the stratospheric transponder platform and the digital beamformer in the ground station using CDMA techniques, for example.

Solar powered stratospheric transponder platforms have the capability of staying aloft for a long period of time, but their weight and power generation capacity are disadvantageously limited. Ground-based digital beamforming removes the weight and power requirements of the beamformer from the stratospheric platform to the ground station, and also provides an advantageous system architecture known as "spokes and

hub." In this architecture, all system data and communications processing functions are co-located in the ground station. Because system data does not have to be passed back and forth between the stratospheric

5 transponder platforms and the ground station, valuable communications resources are conserved, resulting in faster processing time and system response.

An important function performed by communications systems including ground stations in a

10 spokes and hub architecture is acquiring a specific subscriber, i.e., locating the cell in a platform coverage area in which a specific subscriber is located.

FIG. 1 is a diagram illustrating a method 100 for locating a specific subscriber 102 in a coverage area

15 104. According to the method 100, each cell 106 within the coverage area 104 is scanned by stepping a beam 108 from a beamformer located in a stratospheric transponder platform 120 sequentially to each cell 106 until the cell containing the specific subscriber 102 is located.

20 Although a communications satellite is used to illustrate a transponder platform in this example, other transponder platforms may be used, such as unmanned aircraft and antenna towers

In this example, the coverage area 104 is 64 km

25 X 64 km and is divided into 64 cells 106 that are each 8 km X 8 km. The beam 108 is stepped in raster scan fashion from cell to cell in each row, and from one row to the next until the specific subscriber 102 is located, in this example, after stepping the beam 108 30 times. Assuming a

30 dwell time of T, locating the specific subscriber 102 requires from T to 64 T, depending on where the cell

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containing the specific subscriber 102 is located.

Disadvantageously, the method 100 requires an average acquisition time of 32T, or more generally, NT/2, where N is the number of cells in the coverage area.

5 Because N may be a large number, processing the many beams slows acquisition time and thus adversely affects the system response.

SUMMARY OF THE INVENTION

10 The present invention advantageously addresses the needs above as well as other needs by providing a method and apparatus for rapid acquisition of a specific subscriber within a coverage area of a transponder platform.

15 In one embodiment, the invention may be characterized as a method for rapid acquisition of a specific subscriber that includes the steps of defining a coverage area as an arrangement of a plurality of cells wherein one of the plurality of cells includes a specific

20 subscriber; defining a partition of cell clusters wherein one of the cell clusters includes the one of the plurality of cells that includes the specific subscriber; forming a beam to correspond to an area of one of the cell clusters; and scanning the beam to the cell cluster that includes

25 the specific subscriber.

In another embodiment, the invention may be characterized as a ground-based beamformer for rapid acquisition of a specific subscriber that includes a stratospheric transponder platform having an antenna for

30 one of transmitting and receiving a beam; and a ground station coupled to the stratospheric transponder platform

wherein the ground station comprises a beamformer for at least one of zooming the beam to form a beam corresponding to an area of a cell cluster within a partition containing a plurality of cell clusters and scanning the beam to one

5   of the plurality of cell clusters that includes a specific subscriber.

The features and advantages summarized above in addition to other aspects of the present invention will become more apparent from the description, presented in

10 conjunction with the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features and advantages of the present invention will be more apparent

15 from the following more specific description thereof, presented in conjunction with the following drawings wherein:

FIG. 1 is a diagram illustrating a method for locating a specific subscriber in a coverage area;

20   FIG. 2 is a diagram illustrating a method for locating a specific subscriber in a coverage area by zooming and scanning according to an embodiment of the present invention;

FIGS. 3A-3C are beam plots illustrating an

25 exemplary method for zooming a beam that may be used with the method illustrated in FIG. 2;

FIG. 4 is a diagram illustrating the method illustrated in FIG. 2 further enhanced by including a traffic model;

30   FIG. 5 is a block diagram of an exemplary ground-based beamformer that may be used to implement the

methods illustrated in FIGS. 2 and 4; and

FIG. 6 is a flow chart of the method of FIG. 2 for rapid user acquisition for stratospheric transponder platforms by a ground-based beamformer.

5   Corresponding reference characters indicate corresponding elements throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE DRAWINGS

10   The following description is presented to disclose the currently known best mode for making and using the present invention. The scope of the invention is defined by the claims.

The method 100 illustrated in FIG. 1 described
15 above for locating the specific subscriber 102 in the coverage area 104 may be implemented by a ground-based beamformer in a CDMA communications system gateway hub 122. By locating the beamformer at the ground station, the disadvantages of the added weight and power required
20 to include a beamformer in the payload of a stratospheric transponder platform 120 may be advantageously avoided. Also, the separate beam signals and control signals do not have to be passed back and forth between the ground station and the transponder platform, thus reducing the
25 communications traffic overhead of the system. An example of a ground-based digital beamformer will be described later with reference to FIG. 5.

FIG. 2 is a diagram illustrating another method 200 for locating a specific subscriber in a coverage area
30 by performing both zooming and scanning of a beam. The beam may be formed by a beamformer on the transponder

platform or by a ground-based beamformer using the CDMA
communications system in the example of FIG. 1. The
coverage area 104 is defined by the arrangement of a
plurality of cells 106. In this example, each of the
5 cells 106 has the same area. An initial 8 X 8 cell
cluster 201 is defined that, in this example, includes the
entire coverage area. A beam 202 is zoomed to form a beam
that corresponds to the area of the initial cell cluster
201. A locating signal is received from the specific
10 subscriber 102 that confirms that the specific subscriber
102 is in one of the cells 106 included in the initial
cell cluster 201. The initial cell cluster 201 is then
partitioned into four new 4 X 4 cell clusters 204, 206,
208, and 210. The beam 202 is zoomed to become the
15 smaller beam 212 that corresponds to the area of one of
the new 4 X 4 cell clusters 204, 206, 208, and 210 and is
scanned or stepped in raster fashion to each new cell
cluster successively until a locating signal is received
from the specific subscriber 102. The cell cluster
20 containing the specific subscriber 102, i.e., cell cluster
208, is then partitioned into four new 2 X 2 cell clusters
224, 226, 228, and 230. The beam 212 is zoomed to become
the smaller beam 214 that corresponds to the area of one
of the new 2 X 2 cell clusters 224, 226, 228, and 230 and
25 is scanned in raster fashion to each new cell cluster
successively until a locating signal is received from the
specific subscriber 102 in cell cluster 230. The cell
cluster 230 containing subscriber 102 is then partitioned
into four new 1 X 1 cell clusters 234, 236, 238, and 240.
30 The beam 214 is zoomed to become the smaller beam 216 that
corresponds to the area of one of the new 1 X 1 cell

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clusters 234, 236, 238, and 240 and is scanned in raster fashion to each new cell cluster until a locating signal is received from subscriber 102 in cell cluster 240. Because the new 1 X 1 cell clusters 234, 236, 238, and 240

5 now contain only one cell each, the specific subscriber 102 has now been located or acquired.

Only 10 beam steps were required in this example compared to 30 steps in the example of FIG. 1, thus reducing the total dwell time by 67 percent. On average,

10 a dwell time of only 8.5T (based on a minimum of four and a maximum of 13 beam steps) is required for the approach used in this example compared to 32T in the approach of FIG. 1, nearly four times faster.

Another advantage of the method 200 of FIG. 2 is

15 that it may be implemented with existing ground-based digital beamformers simply by adding software using standard beamforming functions and a beam zooming method, such as the one described below. As an example, the ground-based beamformer in a CDMA communications system

20 gateway hub 122 in FIG. 1 can perform the zooming and scanning of the beam 214.

FIGS. 3A-3C are beam plots illustrating a method 300 for zooming a beam that may be used with the embodiment illustrated in FIG. 2. In FIG. 3A, individual

25 beams 302, 304, 306, and 308 each have a width angle θ that corresponds to the area of one of the plurality of cells 106 in FIG. 2. In FIG. 3B, the beams 302 and 304 are added to form a zoomed beam 310, and the beams 306 and 308 are added to form a zoomed beam 312. Each of the

30 zoomed beams 310 and 312 has twice the width angle of the individual beam 302, thus corresponding to a cell cluster

size of 2 X 2, or four cells.

In FIG. 3C, the zoomed beams 310 and 312 are added to form a zoomed beam 320 that has four times the width angle of the individual beam 302, thus corresponding
5   to a cell cluster size 4 X 4, or 16 cells. Other beam combinations may be used according to this method to zoom beams to correspond to the areas of various cell cluster sizes.

FIG. 4 is a diagram illustrating the method
10 illustrated in FIG. 2 further enhanced by a traffic model. A further advantage of beam zooming is realized by adapting to a real-time communications traffic pattern that may have a diurnal cycle and differ from zone to zone within the coverage area. Traffic models may be updated,
15 stored, and accessed in the traffic model by a ground-based beamformer to further reduce the acquisition time. The "spokes and hub" architecture is well suited to the use of traffic models because cell size and search strategy based on traffic conditions and models may be
20 updated at the gateway hub without passing information back and forth between the gateway hub and the transponder platform, thus conserving valuable communications resources.

Special events may have a great influence on the
25 traffic model. For example, an initial 2X2 cell cluster 402 that is smaller than the coverage area 104 may be defined for a known high traffic area stored in the traffic model that contains only four 1 X 1 cell clusters 416, 418, 420, and 422. The beam 202 is zoomed directly
30 to the beam 414 that corresponds to the area of the cell cluster 402, and a locating signal is received from the

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specific subscriber 102 that confirms that the specific
subscriber 102 is in one of the cells 106 included in the
initial cell cluster 402. The initial cell cluster 402 is
partitioned into four new 1 X 1 cell clusters 416, 418,

5 420, and 422, and the beam 414 is zoomed to the beam 415
that corresponds to the area of one of the four new 1 X 1
cell clusters 416, 418, 420, and 422. The beam 415 is
scanned sequentially until the specific subscriber 102 is
acquired in the cell cluster 420.

10   Based on the traffic model, there is a high
probability that the position of the specific subscriber
102 is in the high traffic area defined by the cell
cluster 402, which is much smaller than the entire
coverage area 104. The reduced initial cluster size

15 advantageously reduces the size of the initial cell
cluster and consequently the total dwell time even further
than the method illustrated in FIG. 2. Alternatively, a
sequential search using mixed cell cluster sizes may be
used if only one acquisition code address for subscriber

20 102 (e.g., CDMA systems) is used. If two acquisition code
addresses are used for subscriber 102, the high traffic
area may be allocated a dedicated acquisition code and two
searches may be conducted in parallel using two beams.
One beam would be used to perform the search described

25 with reference to FIG. 2, and the other beam would be used
to perform the search described with reference to FIG. 4.
If the position of subscriber 102 is successfully
predicted by the traffic model, the latter search would be
terminated before the former, thus reducing the

30 acquisition time by the fastest method.
         The traffic model allows the acquisition of the

specific subscriber 102 to be adapted to real-time traffic conditions stored in user position files residing in the gateway station or hub 122. In communications systems having a beamformer in the transponder platform, the

5 traffic model information would have to be transmitted back and forth between the gateway and the transponder platform, which would actually increase the time delay for acquiring the specific subscriber 102. In a ground based beamforming system, however, the traffic model may

10 advantageously be implemented in the ground station without the delay of relaying the traffic model information to the transponder platform.

FIG. 5 is a block diagram of an exemplary ground-based beamformer 500 that may be used to implement

15 the methods illustrated in FIGS. 2 and 4. The ground-based beamformer 500 includes a ground station 52 and a stratospheric transponder platform 54.

Shown in the ground station 52 are a data processor 506 that interfaces in this example with

20 communications traffic 504 to and from internet service providers 502, a traffic model module 508, a digital beamformer 509, beam signals (1-N) 510, element signals (1-M) 512, a CDMA multiplexer/demultiplexer 514, CDMA signals 515, A C- or X- band RF subsystem 516, and a

25 feeder link 518.

The data processor 506 performs multiplexing, demultiplexing, routing, and formatting of beam signals 510 according to well-known techniques. The data processor 506 is coupled to the digital beamformer 509 and

30 includes the functions of beam zooming and scanning beams in raster sequence as described above and illustrated in

FIG. 2.

The traffic model module 508 coupled to the data processor 506 may be included for storing and updating traffic models as described above to further improve
5   subscriber acquisition time as illustrated in FIG. 4. The traffic model module 508 includes the user position files and real-time traffic conditions as described for FIG. 4.

The beam signals 510 are received as input to the digital beamformer 509 when transmitting to the
10 subscribers 534 or generated as output from the digital beamformer 509 to the data processor 506 when receiving signals from the subscribers 534. The digital beamformer 509 receives as inputs or generates as outputs element signals 512 corresponding to the beam signals 510. The
15 digital beamformer 509 may be implemented using well-known techniques. A code division multiple access (CDMA) mux / demux 514 multiplexes / demultiplexes the element signals 512 as described above to/from a C- or X- band RF subsystem 516 according to well-known techniques. The C-
20 or X-band RF subsystem 516 inputs/outputs CDMA signals 515 and transmits/receives C- or X-band signals 517 to/from a feeder link 518 that links the element signals 512 between the ground station 52 and the stratospheric transponder platform 54.

25 The stratospheric transponder platform 54 includes a feeder link 522, a C- or X-band RF subsystem 524, and a CDMA mux / demux 526 that may be implemented according to well known techniques as described above. An S-band RF subsystem 530 amplifies element signals (1-M)
30 528 for transmitting / receiving by an antenna array 532 to/from the subscribers 534 on the beams 108. The

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operation of antenna array 532 is assumed to be reversible between transmit and receive modes, thus the beamforming method of this example applies both to transmitting and receiving signals. The stratospheric transponder platform

5   54 may be, for example, a communications satellite, an unmanned aircraft, or an antenna tower.

For the user acquisition function, the stratospheric transponder platform 54 and the gateway hub 52 only receive the locating signal and do not transmit

10 any signals to the subscriber 534 being acquired. Thus, in FIG. 5, the locating signal originates from the subscriber 534 being acquired and is relayed by the stratospheric transponder platform 54 to the gateway hub 52. When receiving the locating signal from the

15 subscriber 534 being acquired, the inputs to the digital beamformer are the element signals 512 and the outputs are the beams 510. One or two of the beams may be used for user acquisition. The zooming and scanning functions may be performed mathematically in the digital beamformer in

20 two steps: (1) multiplying the M element signals by an appropriate set of M weights represented as complex numbers, and (2) summing the M weighted signals to determine the output beam signal. The sets of complex weights may be computed using well known techniques.

25   FIG. 6 is a flow chart 600 of the method illustrated in FIG. 2 for rapid user acquisition for stratospheric transponder platforms by beams formed by the ground-based beamformer of FIG. 5. Step 602 defines a coverage area as an arrangement of cells such as that

30 shown in FIG. 2. Step 604 defines an initial cell cluster that includes the cell containing the specific subscriber.

The initial cluster may be selected as the entire coverage area or a portion of the coverage area determined by a traffic model as explained above. Step 606 zooms the beam to form a beam that corresponds to an area of one of the

5 cell clusters. Step 608 scans the beam to the cell cluster that includes the specific subscriber. Step 610 partitions the cell cluster that includes the specific subscriber to define a new partition of cell clusters. Step 612 repeats steps 606, 608, and 610 until the

10 partition contains only one cell, i.e., the cell containing the specific subscriber.

Other modifications, variations, and arrangements of the present invention may be made in accordance with the above teachings other than as

15 specifically described to practice the invention within the spirit and scope defined by the following claims.